White paper for Developing an Advanced Fueling System and for supporting Disruption Mitigation studies for ITER on NSTX-U

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This white paper is for the development of an advanced fueling system and supporting disruption mitigation studies using Compact Toroid injection technology, for ITER on the NSTX-U device.

Steady-state Advanced Tokamak (AT) scenarios rely on optimized density and pressure profiles to maximize the bootstrap current fraction. Under this mode of operation, the fuelling system must deposit small amounts of fuel where it is needed, and as often as needed, so as to compensate for fuel losses, but not to adversely alter the established density and pressure profiles[1]. Conventional fuelling methods have not demonstrated successful fuelling of AT-type discharges and may be incapable of deep fuelling high-performance discharges in ITER. The capability to deposit fuel at any desired radial location within the tokamak would provide burn and bootstrap current control capability through alteration of the density profile. The ability to initially peak the density profile would ease ignition requirements. An advanced fuelling system should also be capable of fuelling well past internal transport barriers.

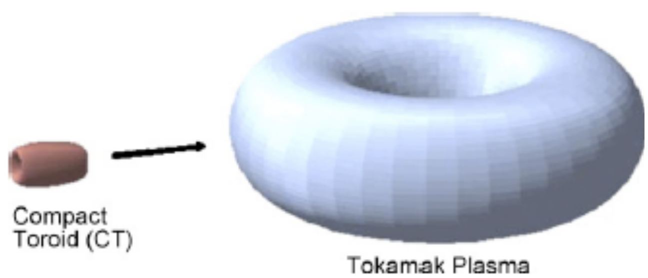

Fig. 1. A self-contained magnetized plasmoid (the CT), with a volume of ~1-2 L is accelerated to a velocity of about 300-500 km/s and injected into the target tokamak. In this figure the CT and tokamak plasmas are not to scale.

Compact Toroid (CT) fuelling (Figure 1) has the potential to meet these needs, while simultaneously providing a source of toroidal momentum input[2]. A fuelling system based on Compact Toroid injection has a simpler fuel cycle, without the need for tritium cryogenics, and should improve tritium usage and reduce tritium inventory in the fuel cycle[3]. Experimental data needed for the design of a CT fueler for ITER could be obtained on NSTX-U using an existing CT injector.

NSTX-U is the most attractive device on which to develop CT fueling for the following reasons.

- To first order, for CT penetration, the kinetic energy density of the CT must exceed the magnetic field energy density in the target tokamak. Because NSTX-U is low field device (B_T = 1), the present CT injector, now in storage at PPPL, with some improvements is well sized for NSTX-U.

- For CT penetration studies, the minor cross-section of the target plasma must be much larger than the dimensions of the CT. This is necessary for localizing the effects of CT injection. This too is well satisfied by NSTX-U.

- Finally, it is very desirable to have a steep gradient in the toroidal magnetic field as this more precisely specifies the CT stopping location. This information is required for scaling studies. Because NSTX-U is an ST, the toroidal field near the center stack is about 10 times that at the outer edge. A conventional large aspect ratio tokamak would not have such steepness in the toroidal field gradient.

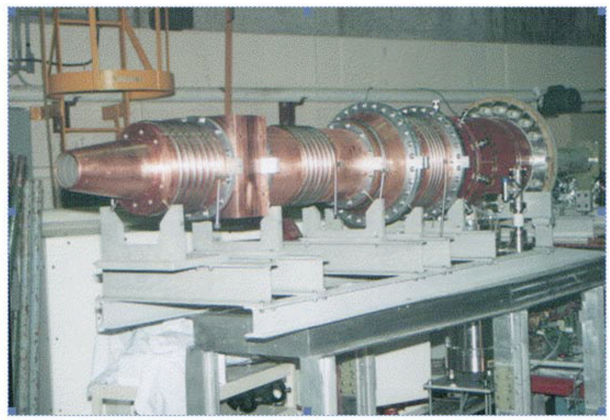

Figure 2: The CTF injector (top right, as initially assembled) has a formation region with measurements of 22.8 cm ID, 30.5 cm OD and a length of 112 cm. The accelerator has an inner diameter of 4.5 cm, an outer diameter of 10.2 cm and a length of 137 cm. The final diameter of the CT after compression in the focus cone is a diameter of 12 cm. All plasma-facing components are coated with state-of-the-art high quality coating of dense tungsten to reduce electrode erosion, and has shown clean fuelling of TdeV[4]. Shown in the second figure (top left) is the 50 kJ CT formation bank power supply. A similar, but larger (100kJ) accelerator bank is used for accelerating the CT.

Figure 2 shows the CT formation capacitor bank and the CT injector. The system can be made functional after a year of off-line commissioning. Figure 3 shows the radial and tangential mounting configurations on NSTX-U.

Studies that could be conducted on NSTX-U are:

- The requirements for localized deep fuelling, as required for density profile control of advanced scenario discharges.

- Tangentially mounted CT injector (Figure 3) for demonstration of momentum injection capability.

- Transport studies by injecting CTs doped with impurities.
- Disruption mitigation studies such as Runaway Electron Mitigation and reducing the amount of gas required by MGI for thermal quench (mentioned in 2010 NSTX Disruption Mitigation proposal to DOE)

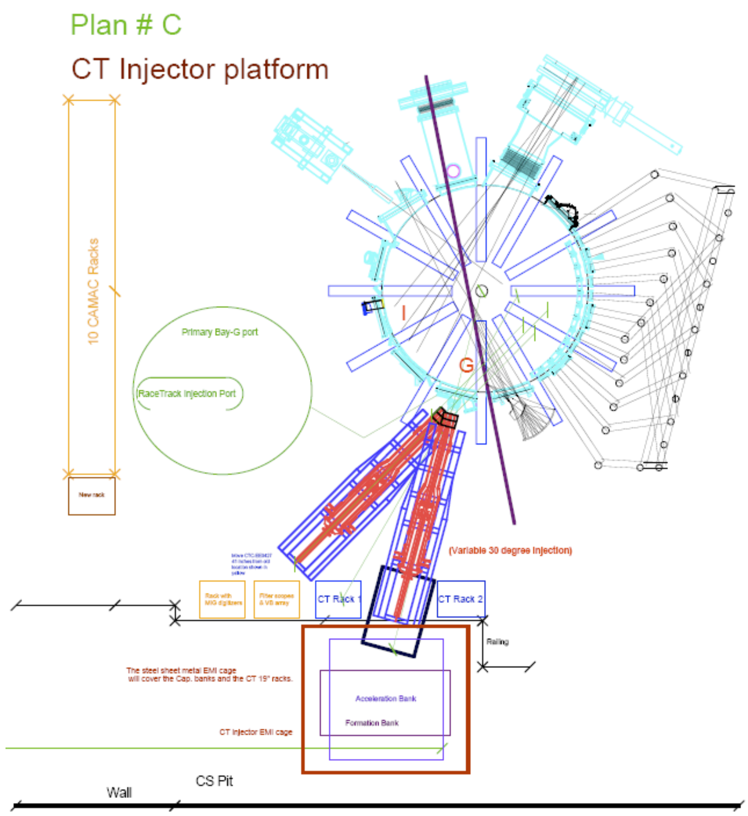

Fig. 3: Proposed layout of the CT injector on NSTX-U. The angle of injection could be varied to study toroidal momentum injection.

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